CLIMATE RISK PROFILE SERIES

ADAPTING GREEN INNOVATION CENTRES TO CLIMATE CHANGE: ANALYSIS OF VALUE CHAIN ADAPTATION POTENTIAL

Maize and rice value chains in the Ashanti, Brong Ahafo, Eastern and Volta regions, **Ghana**

Alliance
Bioversity International
CIAT
International Center for Tropical Agriculture
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
CGIAR
RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security
CCAFS

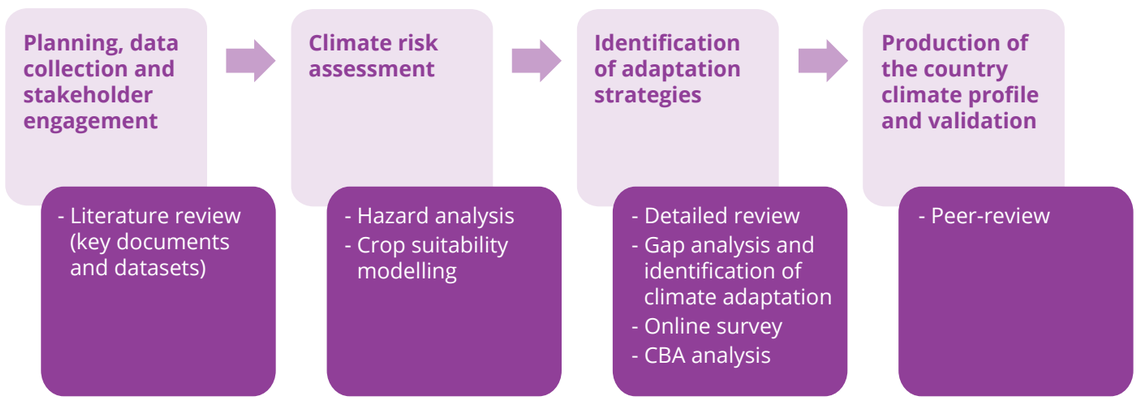
ABOUT THIS REPORT

Climate change is affecting agriculture more than any other sector. Increased frequency and severity of drought, flood, heat, and unseasonable rainfall heavily impact rainfed agriculture, ultimately resulting in production losses. In that context, The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) through its climate action lever, are developing climate risk profiles for agricultural value chains in developing countries at the national and subnational level. These profiles build on past work conducted by CIAT and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)in collaboration with the World Bank and other partners, including FAO, USAID, DFID[1].

The present report aims to provide a climate and vulnerability analysis of the Green Innovation Centres (GIC) target commodity value chains. Herein we identify climate change- related vulnerabilities, hazards, and opportunities for adaptation to the same. Ultimately, our goal is to foster awareness of risks and adaptation priorities in the selected value chains and inform climate investments and planning through the recommendations on priority innovations to manage climate risks.

The report begins with an extensive literature reviews of the selected value chains and their key challenges and adaptation strategies. Climate hazards and crop suitability modelling offer insights into potential future scenarios under climate change. These results inform potential adaptation approaches, which are prioritized by in-country experts and stakeholders through an online survey. The top-rated adaptation priorities undergo a cost-benefit analysis. Finally, the results are peer-reviewed by the GIC country office and the Alliance scientific staff.

The **Green Innovation Centres** for the Agriculture and Food Sector (GIC) founded by German Federal Ministry for Economic Cooperation and Development (BMZ) and led by the German Agency for International Cooperation (GIZ) in collaboration with local ministries and programmes, aims to promote agricultural innovation under the *ONEWORLD No Hunger* initiative. Through the GIC, GIZ aims to generate employment raise farmers' income, and improve farmers' education and skills by funding training in good agricultural practices, water management, post-harvest processing, and entrepreneurship.



1 https://ccafs.cgiar.org/publications/csa-country-profiles

HIGHLIGHTS

- Agriculture is a key sector of the Ghanaian economy that contributes 18.5% of national GDP and employs 65.2% of households in rural areas **(Chapter 2, pg.9).**
- 46% of Ghanaians are multidimensionally poor. A lack of improved water sources, poor access to electricity, and child stunting are particularly prevalent among rural smallholders **(Chapter 2, pg.9-10).**
- Smallholder farmers dominate agricultural production, with an average farm size of 3.8 ha **(Chapter 2, pg.11).**
- Farmers face challenges such as sub-optimal input use, high reliance on rain-fed agriculture, climate hazards, high poverty rates, and low access to credit and extension services **(Chapter 2, pg.16-17).**
- The government has invested in a variety of strategies to increase farmers' resilience **(Chapter 3, pg.18-19).**
- Stronger cooperation between the government and other developmental agencies, more inclusive policies, infrastructure development, and broader access to basic farmer services will support climate resiliency **(Chapter 4, pg.21).**
- Maize and rice are important crops in Ghana; rice is projected to become more suitable under climate change, and maize less so **(Chapter 5, pg.25).**
- Ghanaian farmers have observed changing weather patterns, and further study of their observations could support more effective adaptation interventions **(Chapter 5, pg.21).**
- Conclusively the adaptation potential for the selected value chains is promising. Several adaptation strategies exist that can maximize productivity, reduce costs and increase climate resiliency. They include crop diversification, crop rotation and mixed cropping, application of fertilizer, planting early maturing seed varieties, changing crops species, and shifting planting dates. **(Chapter 6, pg.32).**

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ACRONYMS AND ABBREVIATIONS

AGRA	Alliance for a Green Revolution in Africa
CBA	Cost-Benefit Analysis
CIAT	International Center for Tropical Agriculture
CSA	Climate-Smart Agriculture
CSIR	Council of Scientific and Industrial Research
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIZ	German Agency for International Cooperation
GMet	Ghana Meteorological Agency
GSS	Ghana Statistical Service
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IRR	internal rate of return
MoFA	Ministry of Food and Agriculture
NADMO	National Disaster Management Organization
NGO	non-governmental organization
NPV	net present value
NRDS	National Rice Development Strategy
SMS	short message service
SRI	System of Rice Intensification
US$	United States Dollar

1. INTRODUCTION

Agricultural production remains a significant contributor to the Ghanaian economy because it is a source of livelihoods and employment for many rural households. The agricultural sector is dominated by smallholder farmers characterized by a high poverty rate, sub-optimal use of inputs such as fertilizer and improved seeds, dependence on rain-fed agriculture, and low productivity. It has been hit hard by climate change and its adverse effects, such as changes in rainfall intensity and patterns, increasing temperatures, and more frequent droughts. Future climatic modelling results suggest that this trend will worsen in the coming years, impacting maize production. Nevertheless, the Ghanaian government has realized the need to empower farmers to strengthen their resilience. For this purpose, it has created several programs and policies to address climate change and other agriculture-sector challenges such as land degradation, sub-optimal use of inputs, the high cost of inputs, lack of credit, and poor market linkages. These achievements are exemplified by the National Climate-Smart Agricultural and Food Security Action Plan, the Planting for Food and Jobs Flagship Project, the National Fertilizer Subsidy Program, the National Rice Development Strategy, and the Food and Agriculture Sector Development Policy. The government has also partnered with several development agencies in transforming agricultural production to enhance food security, reduce poverty levels, and achieve a sustainable and profitable sector.

This document presents a climate and vulnerability analysis of the maize and rice value chains in the Eastern, Volta, Ashanti, and Brong-Ahafo regions of Ghana (Figure 1). It aims to inform stakeholders, policymakers, and the private sector about climate change risks and opportunities pertaining to these value chains. It will also help integrate climate change into the national development agenda. This climate risk profile is an output of a collaboration with the International Center for Tropical Agriculture (CIAT), now part of the Alliance of Bioversity International and CIAT. We gathered information through a literature review for the two value chains, and in addition, we carried out climate modelling and crop suitability analysis for the Brong-Ahafo, Ashanti, Volta, and Eastern regions and their value chains.

This climate risk profile has six sections. The first describes the importance of agriculture to people's livelihoods in the four departments. Section two highlights the policies, strategies, and programs implemented in the three value chains that address climate change, while the third section discusses the governance and institutional resources and capacity. The fourth section discusses the main climatic hazards affecting the three value chains and presents climate modeling results for projected climatic change-related hazards and crop suitability maps. Additionally, it offers an analysis of vulnerabilities and risks posed by these hazards to the respective value chains. The ongoing on-farm adaptation strategies adopted by farmers to cope with these hazards as well as the cost benefit analysis results are discussed in the fifth section. The sixth section provides a synthesis and recommendations.

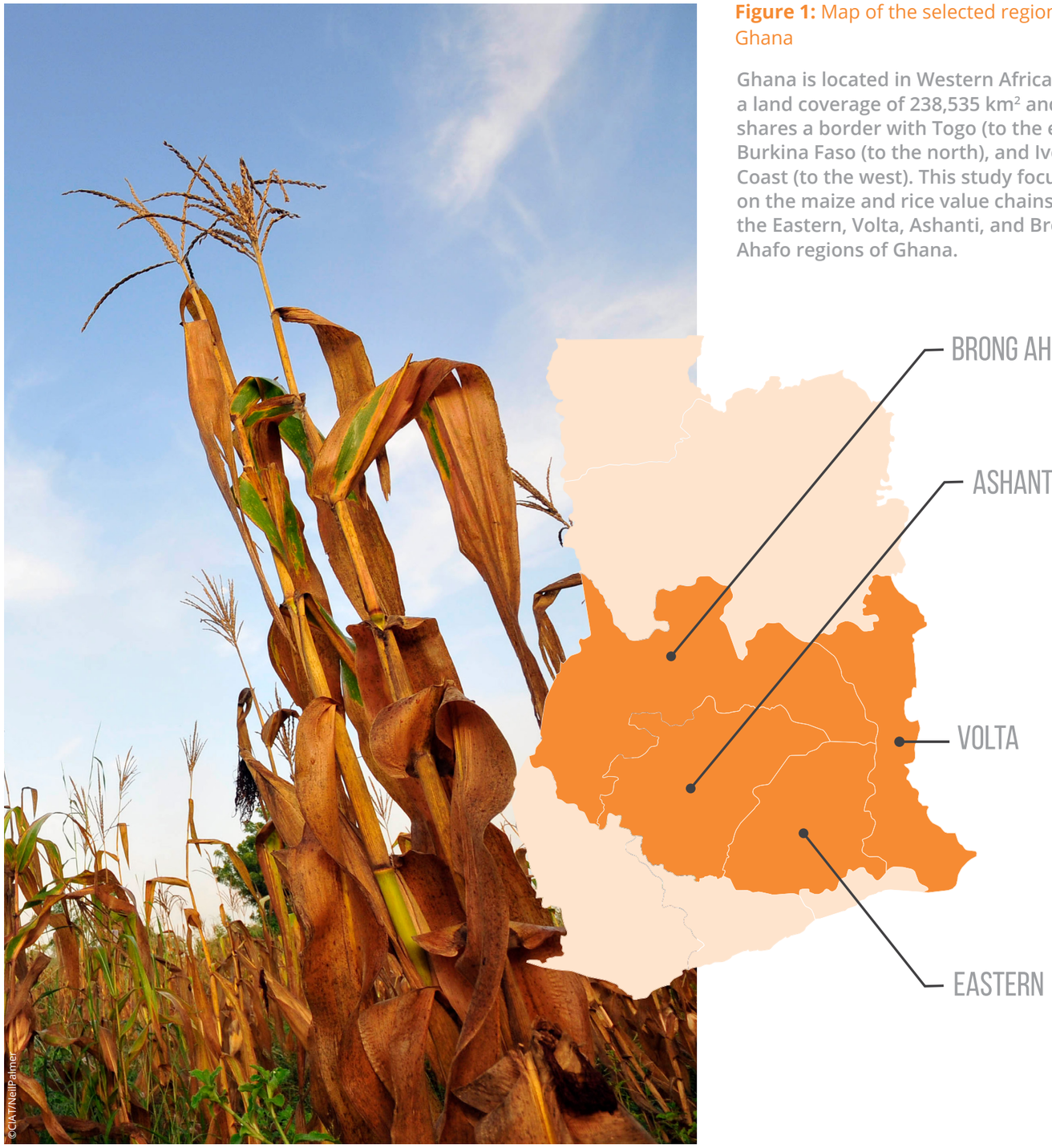


Figure 1: Map of the selected regions in Ghana

Ghana is located in Western Africa with a land coverage of 238,535 km^2 and shares a border with Togo (to the east), Burkina Faso (to the north), and Ivory Coast (to the west). This study focuses on the maize and rice value chains in the Eastern, Volta, Ashanti, and Brong-Ahafo regions of Ghana.

2. AGRICULTURAL CONTEXT

KEY MESSAGES

- Agriculture is essential to the Ghanaian economy, employing most rural households (65.2%).
- Heightened agricultural productivity is vital to alleviating Ghana's high poverty rate.
- Farmers must navigate issues such as overreliance on rain-fed agriculture, costly inputs, sub-optimal input use, low productivity, low access to credit and markets, and climatic hazards.
- Maize and rice are important to Ghanaian food security.

2.1. Economic relevance of farming

The agricultural sector remains critical. It contributed, on average, 18.5% to the Ghanaian gross domestic product (GDP) in 2019, a decline from 21.7% in 2013, according to the Ghana Statistical Services (GSS, 2020a). Crop cultivation is an important sub-sector, contributing 13.5% to the GDP, and cocoa, which contributes 1.4%. Livestock, forestry, and fishery sub-sectors contribute 2.5%, 1.3%, and 0.9%, respectively. This reaffirms the importance of cocoa farming to the economy, even though its contribution declined from 2.3% in 2014 (GSS, 2020a). However, the cocoa sector has been growing at an annual rate of 5.4%, higher than crop sub-sector and the entire agricultural sector at 5.3% and 4.6%, respectively, as estimated in 2019 (GSS, 2020a).

The agricultural sector employs 38.3% of the total national workforce. This percentage represents a decrease from 41.2% in 2010 (GSS, 2015), but within rural areas, it employs 65.2% of the workforce, of which 65.9% are male and 60.7% female (GSS, 2016; GSS, 2019).

2.2. People and livelihoods

Ghana's population is projected to be 31.0 million people. The Ashanti Region is predicted to be the most populous at a population of 5.9 million, followed by Eastern at 3.3 million, Brong-Ahafo at 2.7 million, and Volta at 1.9 million (GSS 2020b). From the early 2000s, the population growth rate has been declining slightly from 2.4% to 2.2% in 2018. Nevertheless, a majority of the population is between 0 and 14 years old. An average household consists of 3.8 persons per family, a reduction from 4.4 persons in 2010 (GSS 2019) (Figure 2).

The poverty rate and access to basic goods and services such as water and electricity are a good measure of people's wellbeing. Nearly 45.6% of Ghanaians can be classified as multidimensionally poor (GSS, 2020c).[2] In rural areas, poverty rates are relatively higher at 64.6% and lower within urban areas at 27%. By region, Volta has the highest multidimensional poverty rate at 58.2%, followed by Brong-Ahafo at 49.4%, Eastern at 44%, and Ashanti at 31.1%. When compared to the conventional monetary measurement of poverty (people living below the US $1.9 per day), 23.4% of Ghanaian are poor. Among Ghanaians struggling with poverty, 39.6% of them live in the rural area and 7.4% in urban areas. Based on the 2010 census report, 69% of the households classified as poor were employed in the agricultural sector (GSS, 2015). **Since most rural households are employed in the agricultural sector, enhanced agricultural productivity and rural development are key to alleviating poverty.**

Electricity is the primary source of lighting for most homesteads. 89.2%, 75.3%, 73.8% and 72.5% of homesteads are connected to the national grid in Ashanti, Volta, Eastern, and Brong-Ahafo, respectively. About 86% of households have access to improved sources of drinking water (GSS, 2018). The percentage is higher in urban households at 95.8%, compared to 77.5% in rural areas. By region, Volta region has the lowest access levels at 65.1%, compared to Eastern (85.8%), Brong-Ahafo (92.4%), and Ashanti (92.6%).

Firewood and charcoal are the most common sources of cooking energy in Ghana and among the rural population. In rural areas 63.0%, 22.0%, 8.7% utilize wood, charcoal, and gas as their main sources of cooking energy (GSS, 2019); in urban areas, the proportions stand at 11.3%, 44.3%, and 34.8%. In urban areas, the use of charcoal is relatively higher, since charcoal produces lower levels of smoke than firewood and is cheaper than gas.

Ownership of mobile phones and access to the internet is currently viewed as an essential tool in the dissemination of crucial agricultural production information (Folitse et al., 2019). National ownership of mobile phones stands at 92.5% and internet usage at 22.4% (GSS, 2018). This provides an excellent foundation to enhance extension services by means of short messages services (SMS), since internet usage is still low in Ghana.

Access to credit in Ghana is quite low at 7.1%, which deters farmers from investing in capital-intensive agricultural practices such as irrigation. Credit has been found to influence the uptake of agricultural practices (Darkwah et al., 2019). However, in rural areas, 8.1% of households had access to credit, compared to 6.2% in urban areas. The main reasons behind the low uptake of credit are high interest rates and demand for collateral. In rural areas, the main sources of credit include Susu schemes, saving and loan programmes, relatives, friends, and private banks.[3] Credit is essential in smoothening household consumption patterns and investing in agricultural production.

The national youth literacy level is a crucial measure of a country's progress in providing education for all. In Ghana, the youth literacy level is estimated at 56.4%, with young women at 55.0% and young men at 56.4% (GSS, 2019). There exists a significant disparity in youth literacy levels between rural areas (50.5%) and urban areas (61.8%). This disparity is of concern. Moreover, Ghana's average youth literacy level falls well below the global rate of nearly 90%. **Low literacy limits the ability of youth to help transform the Ghanaian economy.**

The nutritional status of Ghanaian children below five years of age indicate that only 6.8% of Ghanaian children are wasted, 17.5% stunted, and 12.6% underweight (GSS, 2018). These statistics reflect good eating habits. In Ghana nearly 42.9% of a household expenditure is utilized to purchase food. Among rural households, the percentage is slightly higher at 50.6%, whereas it is lower in urban areas at 39.2%. The high rate in rural areas is worrying because most rural agricultural households consume more of their produce than urban agricultural households. Increased expenditure on food reduces a household's ability to invest in agricultural innovation and modern inputs.

2 Multidimensional poverty characterizes a person who is deprived of at least three basic needs: namely, electricity, water, housing, assets, cooking fuel, sanitation, school attendance, nutrition, and health insurance.

3 A Susu scheme is an informal banking system in which regular and periodic (daily or weekly) deposits of fixed amounts are made to collectors. Depositors can access their money after a specified period or by taking up a loan. Borrowing under a Susu scheme does not require collateral, making it strongly preferrable to most people and small business enterprises.

2.3. Agricultural activities

57.1% of Ghana's total land area is considered agricultural, but only 18.11% is under cultivation and 0.03% under irrigation. The average farm size in Ghana is 3.81 ha, with slight variation across the four regions. In Volta, it is 4.13 ha, 2.19 ha in Brong-Ahafo, 1.98 ha in Ashanti, and 1.87 ha in Eastern (GSS, 2019). The primary land tenure system for 80% of farmers in Ghana is the customary tenure system governed by traditional rulers, mainly chiefs. The government can exercise compulsory land acquisition rights whenever it needs to develop social amenities or correct economic and social inefficiencies in the private market and distribution of land. In customary land tenure, women possess the rights to own and inherit land, but this fact is in most cases overlooked even though they are protected under the laws of Ghana.

As previously mentioned, crop farming is the main agricultural activity in rural areas, nationally 44.1% of households owning or operating a farm. This rate is even higher in rural areas at 74.4% (GSS, 2019b). At the regional level, 66.7% of household in Volta own and operate a farm, 62.3% in Brong-Ahafo, 58.7% in Eastern, and 29.9% Ashanti. The Ashanti, Brong-Ahafo, and Eastern regions contributed to a nearly 56% and 66% of the estimated annual value of crops harvested and sales respectively; this signifies that these three regions have promising agricultural productivity potential and a high level of commercialization compared to other regions of Ghana. The five most important crops in Ghana in term of value of harvest are cocoa, cassava, yams, maize, and plantains. Nearly 40% of all Ghanaian households cultivated maize and cassava, which are well suited to most of Ghana's agroecological zones. Excepting plantains, the other four crops – cassava, maize, yams, and cocoa – constitute 56.4% and 54.5% of the total value of harvested crops and their total annual value, respectively. Apart from crop cultivation, other vital sources of income in the agricultural sector include hunting game, the production of shea nuts, the sale of fruits, the collection of wild fruits, and fishing.

Poultry and goats are the most common forms of livestock reared in Ghana, followed closely by sheep and cattle, with donkeys and bulls reared in small numbers mainly to provide traction. Chickens constitute nearly 90% of this poultry, and Ghana also produces guinea fowl and turkeys. Poultry is mainly reared for eggs and as a source of white meat. The primary livestock rearing areas include the Northern, Volta, Brong-Ahafo, Eastern, and Upper East regions, which together contribute 77% of the total value of Ghanaian livestock.

On average, input usage is still low with Ghana. Usage of organic fertilizers, improved seeds, inorganic fertilizers, and herbicides stood at 3%, 9.1%, 12.6%, and 23.9% respectively (GSS, 2019). However, these inputs were unobtainable to 59.8% of households engaged in agriculture. This statistic is discouraging given the government's extensive efforts to subsidize fertilizer and improved seeds to enhance their accessibility and affordability. The primary sources of labour are household labour and animal traction at 88%, hired labour at 21%, and 1% hired animal traction.

Value addition for agricultural products is only practiced by 24.5% of households and is very much dominated by women (90.2%). 35% of rural households are engaged in value addition compared to 16.3% of urban households. The most common processed products include corn and cassava flour and dough, and flour from other grains. In addition, rice husking and polishing are on the rise.

Access to extension service remains low. Extension services are crucial to relay research findings and train farmers in the latest agricultural technologies and innovations. Sub-optimal usage of agricultural inputs limits farmers' productivity, and is generally a result of poor extension service delivery methods rather than farmers' unwillingness to access and use the inputs (Anang et al., 2020). Farmer groups and non-governmental organizations (NGOs) have become increasingly prominent providers of extension services over the past several years. The government and NGOs can take advantage of high mobile phone ownership and relay information to farmers by SMS.

Ghana has six distinct agroecological zones: rain forest, deciduous forest, the transitional zone, the Guinea savannah, the Sudan savannah, and the coastal savannah. The Eastern and Ashanti regions are within the deciduous forest zone, with the northern parts of the two regions in the transitional zone. Volta includes parts of the coastal savannah to the south and the Guinea savannah to the north, and is mostly deciduous forest. Brong-Ahafo, meanwhile, includes deciduous forest to the south and parts of the Guinea savannah to its extreme north, as well as the transitional zone in between these. The agroecological zones differ in terms of annual rainfall, the length of their growing seasons, and their main food crops, as shown in Table 1 below (FAO, 2005; Kemausuor et al., 2013).

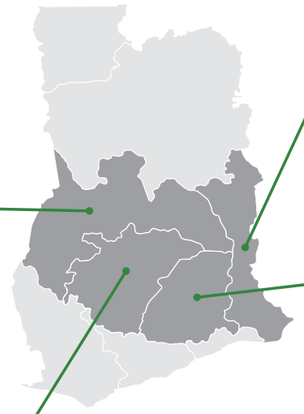
Table 1. Ghana Agroecological Zones

ZONE	MEAN RAINFALL (MM)	LENGTH OF THE GROWING SEASON (DAYS)	MAIN CROPS
Rain forest	2200	150-160	• Cassava, plantain, maize, oil palms
Deciduous forest	1500	150-160	• Cocoa, cassava, plantains, maize, oil palms
Transition zone	1300	180-200	• Cassava, maize, yams, plantains, groundnuts, cowpeas,
Guinea savannah	1100	180-200	• Sorghum, maize, groundnuts, cowpeas, yams
Sudan savannah	1000	150-160	• Millet, sorghum, maize, groundnuts, cowpeas, yams
Coastal savannah	800	100-110	• Cassava, maize

Figure 2. Livelihoods and agriculture in Ghana

DEMOGRAPHICS

GHANA'S POPULATION
28,956,587



Brong Ahafo 10%
2,723,050 inhabitants
56% of which are **rural**

Volta 9%
2,491,293 inhabitants
66% of which are **rural**

Eastern 11%
3,099,641 inhabitants
57% of which are **rural**

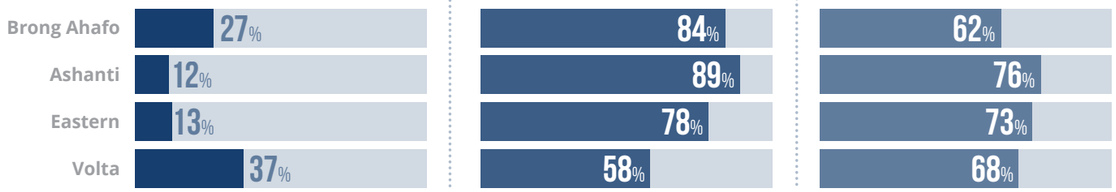
Ashanti 19%
5,533,011 inhabitants
39% of which are **rural**

ACCESS TO BASIC NEEDS

% of the population suffering from **absolute poverty**

% of households with access to **potable water**

Youth literacy rate (15-30 years)



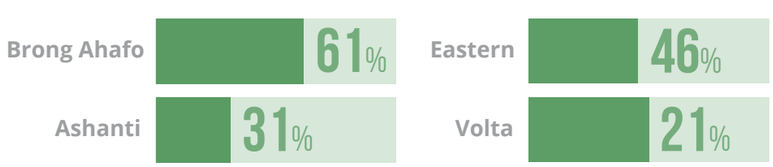
% of households with access to **electricity for lighting**

% of households with access to **electricity for cooking**

BRONG AHAFO	ASHANTI	EASTERN	VOLTA
0.3%	0.6%	0.2%	0.0%

FARMING

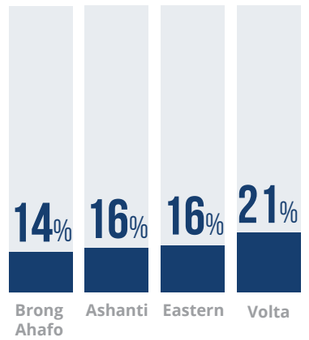
% of the population **employed** in agriculture production



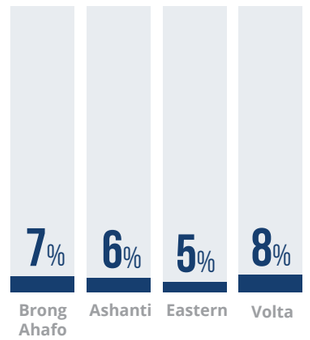
FOOD SECURITY

Population suffering from **food poverty**

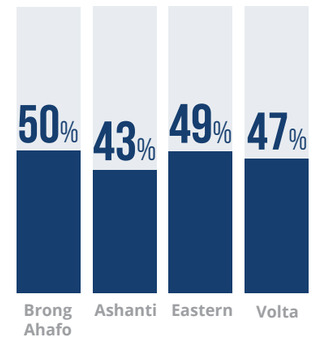
% of **children stunted**



% of **children wasted**



% of **household income** spent on food



FARMING ACTIVITIES

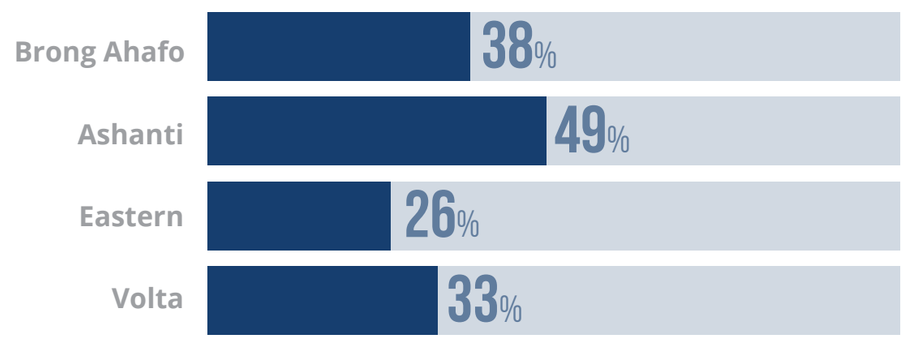
93.0%* Food crops

Cash crops **1.7%***

* National data, not disaggregated per region

FARMING INPUTS

Fertilizer usage as a % of households



2.4. Agricultural value chain commodities

Ghana has a broad diversity of agricultural production systems, with several value chains prioritized for development interventions by the government and other organizations and programs. **The Green Innovation Centres selected the maize and rice value chains for their potential contributions to food security and their regional and national importance.**

2.4.1. Maize

Maize is a crucial crop for Ghana; it accounts for a quarter of the calories consumed there and for 55% of Ghana's total grain production (FAO, 2012; GSS, 2018). In 2018, 2,306,400 metric tons of maize were produced in Ghana, which represents a 42.4% increase from 1,619,600 metric tons in 2009. Over the years, maize productivity has improved from 1.2 to 1.9 metric ton/ha following the successful implementation of the National Fertilizer Subsidy Program, whereby fertilizer application has increased to 13 kg/ha compared to 8 kg/ha in 2008 (Houssou et al., 2017; Scheiterle and Birner, 2018a). Nevertheless, productivity is below 4-6 metric ton/ha yield from on-farm trials (Scheiterle and Birner, 2018a). The primary maize-producing regions include Brong-Ahafo, Eastern, Northern, and Ashanti, but maize is produced in the entire county.

Over 50% of this maize is used for own production in the form of maize flour and boiled or roasted green maize. Of marketed maize products, 42% are processed and/or turned into animal feed (Darfour and Rosentrater, 2016). With an increasing demand for poultry feed, the demand for maize has been rising at a rate of 10% per year. **This creates an opportunity to enhance local production, considering that Ghana reported importing 267,000 metric ton in 2015 (FAO, 2015).**

70% of maize producers are smallholder farmers. Sowing starts in April and harvesting in September in the south, while in the north, the season ranges from June to October. Maize production is mainly characterized by low input usage and low mechanization, with the exception of fertilizer use, which has been increasing due to the success of the National Fertilizer Subsidy Program (Houssou et al., 2017). After production, farmers usually sell their produce at local markets to aggregators called "market queens," who predominantly sell to larger wholesalers (FAO, 2012; Scheiterle and Birner, 2018b). Processors, in turn, purchase maize from wholesalers before turning it into maize flour and animal feed. Through informal channels, white maize is exported to Ivory Coast; formal statistics recording quantities do not exist.

2.4.2. Rice

In 2018, 769,400 metric tons of rice were produced in Ghana, a 96.6% increase from 391,400 metric tons in 2009. At the same time, the land under rice cultivation has increased slightly from 224,000 ha to 259,700 ha between 2014 to 2018. Productivity has improved over the last two decades due to the government's support programs, such as its fertilizer subsidy program. Due to the increasing demand for rice in Ghana, rice importation accounted for nearly 60% of the total agricultural imports per year between 2014 and 2019 (GSS, 2020d). Because local rice production only satisfies 30-40% of the total demand and because of Ghana's high reliance on rice importation, the government formulated the National Rice Development Strategy (NRDS) to double domestic production and maintain a 10% annual production growth rate. Additionally, it imposed a 20% import duty to encourage local production (FAO, 2013).

80% of rice producers are smallholder farmers. The primary producing regions are Northern, Volta, and Upper (AGRA, 2012). The main production systems are irrigated, upland rain-fed, and lowland rain-fed systems, with the latter being the most common. However, irrigated paddy rice has a higher production capacity compared to the rain-fed production system. Like maize production, rice production is characterized by low input use and output; however, over the years, several programs such as the NRDS and the National Fertilizer Subsidy Program have aimed to increase fertilizer use and improve rice varieties.

After harvesting, most farmers mainly sell their rice in paddy form, without any value addition. The main buyers are wholesales and millers. Compared to other regions, Volta and Northern have a more developed rice processing and marketing channel with integrated commercial players. The main value addition activities along the rice value chain include milling, sorting, grading, and packaging. In Ghana, consumers have a strong preference for imported rice because they perceive it is higher quality than locally produced rice (Roger, 2012). For instance, locally produced rice is rarely sold in supermarkets since 80% of urban consumers prefer imported rice. The main problems facing rice production include high production costs compared to Asian countries, low-quality seeds, low mechanization, and poor infrastructure such as roads and storage.

2.5. Agricultural sector challenges

The Ghanaian agricultural sector faces several urgent challenges, including the adverse effects of climate change. Changes in temperature and in the pattern and intensity of rainfall harm farmers' productivity, capacity, and livelihoods. These hazards result in crop failure, low germination rates, and incidence of pests and diseases, resulting in low production. Coupled with a high poverty rate and dependence on agriculture for employment, climatic hazards reduce farmers' ability to meet their basic needs. Some regions are experiencing low soil fertility and land degradation, which worsens the situation.

Sub-optimal use of inputs and mechanization reduces farmers' ability to enhance productivity and achieve food security. The fertilizer application rate as of 2017 was estimated at 13 kg/ha, an increase from 8 kg/ha in 2008, with only 5% of the farmers using hybrid seeds (Houssou et al., 2017; Pauw, 2018). Although the National Fertilizer Subsidy Program has helped increase fertilizer use, the application rate remains low compared to other countries in the region and world. For instance, in Kenya, fertilizer application is estimated at 38.2 kg/ha, in Ivory Coast at 51.7 kg/ha, in South Africa at 58.5 kg/ha, in Latin America at 140.2 kg/ha, and in East Asia at 331 kg/ha (World Bank, 2020). This is a key challenge because the use of fertilizer and of improved seeds can increase productivity.

As mentioned above, farmers' inability to invest in agricultural production is due to the high cost of inputs and low access to credit. The exchange rate largely controls the price of fertilizer and chemicals, since nearly all inorganic fertilizer in Ghana is imported. Additionally, it has come to light that several suppliers sell adulterated agrochemicals, fertilizer, and seeds, which even further reduces farmers' willingness to purchase these inputs (Imoro et al., 2019).

Market access and pricing remain a challenge in the agricultural sector. Price fluctuations and differentials between urban and rural areas are common. With the market largely controlled by wholesalers and brokers, prices offered to farmers remain low and fluctuate within each growing season. Additionally, poor road infrastructure reduces access to markets. Upgrading markets would help create a conducive trading environment, while the installation of coolers is likely to encourage the production of horticultural products.

3. POLICIES, STRATEGIES AND PROGRAMS ON CLIMATE CHANGE

KEY MESSAGES

- The Ghanaian government has formulated policies and strategies to support farmers in adapting to climate change and enhancing food security.
- Key examples include the National Climate-Smart Agricultural and Food Security Action Plan, the Drought Management Plan, the Planting for Food and Jobs Flagship Project, the Ghana National Fertilizer Subsidy Program, the National Rice Development Strategy, Vision 2020, and Food and Agriculture Sector Development Policy.

In Ghana, the national government is responsible for the formulation of national agricultural policies, strategies, implementation plans, and budget allocation. **Based on this mandate, the national government has formulated several policies, strategies, and programs to foster adaptation to climate change along the two prioritized value chains.**

The National Climate-Smart Agricultural and Food Security Action Plan (2016-2020) has helped develop and promote the climate-resilient cropping system implemented by MoFA, and the early warning mechanisms implemented by the National Disaster Management Organization (NADMO) and the Ghana Meteorological Agency (GMet). The plan encompasses six thematic areas: namely, agriculture and food security, natural resource management, disaster preparedness and response, energy, industrial and infrastructure development, and equitable social development. The plan is important because it helps solve some of the challenges facing Ghanaian farmers, including poor infrastructure, vulnerability to disasters such as floods, and low productivity. The agriculture and food security thematic area is key. It aims at promoting climate-smart agricultural practices to farmers to improve adaptation and mitigation capacity and enhance social development.

The Drought Management Plan encourages the use of climate services and drought-tolerant crop varieties among farmers, and supports expanded irrigation capacity, water harvesting technologies, and soil management measures that reduce evaporation and erosion, such as mulching and cover cropping. The plan prioritizes sustainability and prolonged impact. Its successful implementation is key. Not only does it cushion farmers from drought-related risks. It also helps increase productivity by enhancing soil fertility and reducing soil degradation through soil and water management practices and the adoption of CSA practices.

The Planting for Food and Jobs Flagship Project, launched in 2017 by MoFA, seeks to improve efficiency, achieve food security, and heighten profitability through increased agricultural productivity as the basis for industrialization, job creation, and export. This project also targets the use of greenhouse technology, the rearing of livestock, agricultural mechanization, and export under the Planting for Export sub-project. These goals are key to attracting youth into lucrative agricultural value chains like vegetables. The project also helps solve fundamental problems farmers faces such as a lack of market infrastructure, market coordination challenges, and low mechanization capacity.

The Ghana National Fertilizer Subsidy Program, launched in 2008, provides farmers with affordable fertilizer to enhance food production. Under the subsidy program, farmers are given vouchers for purchasing the subsidized fertilizer at half the market price from certified local or regional sellers. The program has successfully broadened access to quality affordable fertilizer, with the result that fertilizer application rates have increased. They still, however, fall below the program's target of at least 50 kg/ha. This ongoing program also targets improved seeds delivery, another way of augmenting farmers' access to and use of inputs.

NRDS, developed in 2009 in support with the Coalition for African Rice Development, aimed to double rice production in Ghana. NRDS intervention strategies include augmenting farmers' access to improved seeds, fertilizer, markets, and credit to enable mechanization. The project enabled research and breeding of varieties suitable to lowlands and inland valleys, as well as varieties with greater nitrogen use efficiency and salt-tolerance. It also supported the dissemination of information and development of distribution channels to increase farmers' access to new technology. NRDS has been essential to boosting rice productivity.

Through Vision 2020, the Ghanaian government worked to increase agricultural productivity through sustainable natural resource management, rural development, and export diversification. To achieve the objectives of Vision 2020, the Accelerated Agricultural Growth and Development Strategy was launched in 2001. This strategy focused on increasing agricultural growth from 4% to 6% through the promotion of small-scale irrigation, the use of inputs, and agricultural intensification in high potential areas. Additionally, it sought to broaden farmers' access to financial services and enrich institutional human resources and capacity. These strengthened institutions in turn aid in the dissemination of information, research, implementation, and the intervention support. Although the objectives of Vision 2020 were not fully achieved, this effort was instrumental to achieving Millennium Development Goal 1, reducing extreme poverty by half.

The Food and Agriculture Sector Development Policy, formulated by MoFA, strives to enhance food security, heighten emergency preparedness, raise farmers' income, enable sustainable management of land and the environment, and increase the competitiveness and integration of domestic and international markets. This policy not only augments farmers' access to markets but also supports sustainable land management and access to inputs. It fosters the adoption of CSA, post-harvest, and irrigation and water management practices, as well as value addition. All these improvements are key to solving major challenges to the agricultural sector.

4. GOVERNANCE, INSTITUTIONAL RESOURCES AND CAPACITY

KEY MESSAGES

- Numerous public and private institutions, including government agencies, CSIR institutes, and NGOs, are active in the Ghanaian agricultural sector.
- Successful implementation of government policies and strategies requires strengthening institutional capacity.
- In addition, robust collaboration between the government and other developmental agencies is key to effective climate resiliency.

Several public and private organizations are directly and indirectly involved in the agricultural sector in the four regions. These organizations include government institutions, NGOs, farmer-based organizations, and youth and women's groups, and research institutions. The national government is mandated to conduct research and formulate national agricultural policies. These tasks are achieved through various organs of the national government; namely, MoFA, the Forestry Commission, the Volta River Authority, the Center for Scientific Research into Plant Medicine, the Environmental Protection Agency, the Export Developmental Protection Agency, the Grain and Legumes Development Board, the Irrigation Development Authority, the Land Commission, the GMet, NADMO, the Water Resource Commission, the Ghana Veterinary Council, the Fisheries Commission, and the Ghana Cocoa Board. In term of scientific research, CSIR is mandated to conduct research and inform government policies. To achieve these ends, several institutes under CSIR conduct agricultural research: namely, the Animal Research Institute, Crops Research Institute, Food Research Institute, Forestry Research Institute of Ghana, Oil Palm Research Institute, Plant Genetic Resources Research Institute, Savanna Agricultural Research Institute, Soil Research Institute, and Water Research Institute. CSIR also works hand in hand with universities and several international research institutions such as the International Food Policy Research Institute (IFPRI), CIAT, and the International Institute of Tropical Agriculture.

Several NGOs and developmental partners are actively involved in the Ghanaian agricultural sector in the four regions. They include GIZ, Africa Rising, the International Fund for Agricultural Development (IFAD), the World Bank, the Food and Agriculture Organization (FAO), the United States Agency for International Development, the Alliance for a Green Revolution in Africa (AGRA), and the Ghana Grains Council. IFAD is implementing the Ghana Agricultural Sector Investment Programme, whereby it links farmers of maize, rice and other target crops VC to agribusiness, promoting and mainstreaming climate change resilience approaches. The World Bank, through the Sustainable Land and Water Management Project (2011-2020), is training farmers in water management technologies and the use of organic fertilizer. The FAO promotes conservation agriculture and integrated pest management for sustained soil fertility and productivity. Rising Africa, with funding from Feed the Future, is training farmers in post-harvest handling techniques, distributing maize shelling machines, and connecting farmers with local manufacturers of these devices.

However, problems still arise in the implementation of these diverse projects by the above-mentioned stakeholders. Some institutions have embraced the power of collaboration to facilitate implementation and mutual learning. On the other hand, some organizations work in isolation, leading to the duplication of projects and waste of resources. Other institutions, in addition, lack the technical, financial, and human resource capacity required to successfully implement their projects to strengthen farmers' resilience against the adverse effects of climate change.

5. CLIMATE CHANGE-RELATED RISKS AND VULNERABILITIES

KEY MESSAGES

- Droughts, high temperatures, and floods are the main climatic hazards in Ghana.
- Under climate change, rice production is projected to increase while maize production decreases.
- Farmers are aware of changing weather patterns, and deeper sensitivity to their perceptions about climate change can underpin inclusive policies to strengthen their resilience.

5.1. Farmers' perceptions on climate change

Different agricultural stakeholders have diverse views and perceptions of climate change and its impact on agricultural productivity. A better understanding of their perceptions will facilitate the design of more inclusive policies that can help enhance farmers' resilience to climate change. Farmers' perceptions and knowledge influence their willingness to adopt and accept new agricultural technologies.

Ghanaian farmers indicate that they have noticed changes in weather patterns over the years (Acquah and Onumah, 2011; Fosu-Mensah et al., 2012; Amadou et al., 2015; Yamba et al., 2019). The most noticeable changes involve temperature and rainfall intensity and patterns, with a majority of farmers reporting an increase in temperature over the last 30 years across all regions (Acquah and Onumah, 2011; Fosu-Mensah et al., 2012; Amadou et al., 2015; Yamba et al., 2019). Meteorological data from various stations in Ghana have established this perception as valid. A majority of farmers also observed that rainfall intensity has decreased and become more erratic, thus interfering with their planting dates (Acquah and Onumah, 2011; Fosu-Mensah et al., 2012; Amadou et al., 2015; Yamba et al., 2019). However, meteorological data diverge from this perception, indicating that the mean annual rainfall has slightly increased over the years in some regions. The difference between farmers' perceptions and the meteorological data, however, can be explained by the fact that rainfall patterns have been more erratic, demonstrating higher interannual variability (Amadou et al., 2015). Farmers interpret this high interannual variability as reduced rainfall intensity since the water demand of their crops is high. Additionally, late-onset and lengthened dry spells have been reported and confirmed by climatological data. Late-onset and dry season heavily influence the length of the growing season and, consequently, productivity.

5.2. Climate change and variability: historic and future trends

The Brong-Ahafo, Ashanti, Volta, and Eastern regions have very similar climatic conditions, although the amount of rainfall they receive varies. They all have two growing seasons (Figure 3), with rains in the first season starting in March and ending in July, and in the second season starting in August and ending in November. The mean maximum and minimum temperatures in the four regions range between 34°C and 20°C.

Current and future trends indicate that across these four regions, the number of consecutive dry days (Figure 4), the number of days with a temperature above or equal to 35°C (Figure 5), and moisture stress have all been rising, and they will continue to do so in the future. These trends will pertain mostly to the first season rather than the second. There may also be an increased probability of drought. However, moisture stress will occur in both the first and second season across the four regions.

The length of the growing season and the start of the season are also expected to change (Figure 6). The length of the growing season is likely to decrease in both first and second season, but only slightly in the second season. On the other hand, it is expected that there will be delays in the start of the first season, but conversely, early onset of the second.

Figure 3. Historical monthly mean temperature and precipitation (average of last 30 years) for the Brong Ahafo region of Ghana. Bars represent total monthly precipitation, whereas lines represent maximum (red line) and minimum (blue line) monthly mean temperatures.

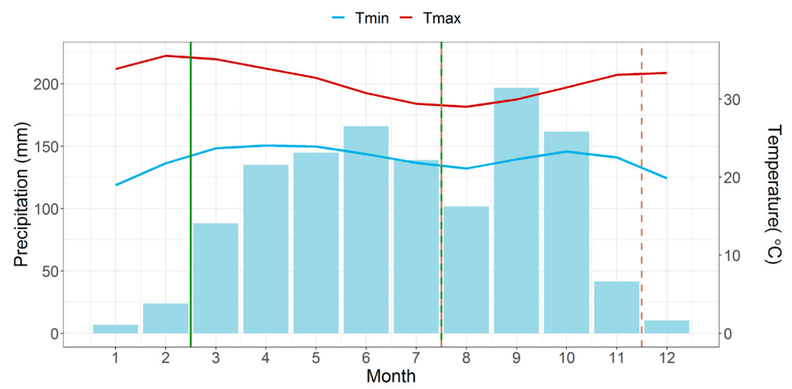


Figure 4. Historical (left), future projected (center) and projected change (right) for the maximum number of consecutive dry days in the first season (average of last 30 years) for the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.

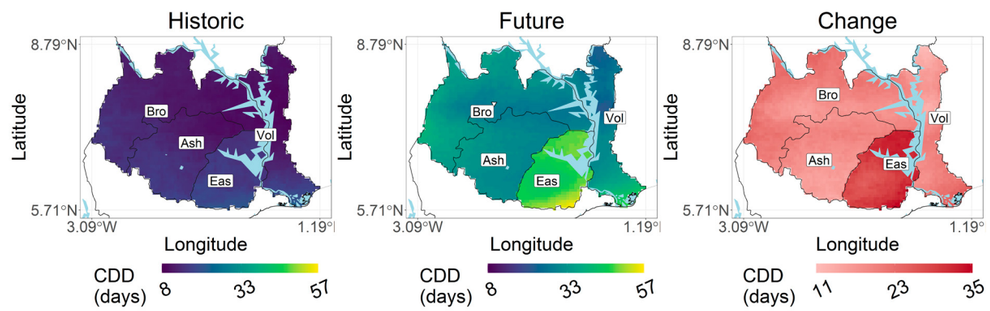


Figure 5. Historical (left), future projected (center) and projected change (right) for the total number of days with maximum temperature greater or equal to 35°C for the first season (average of last 30 years) for the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.

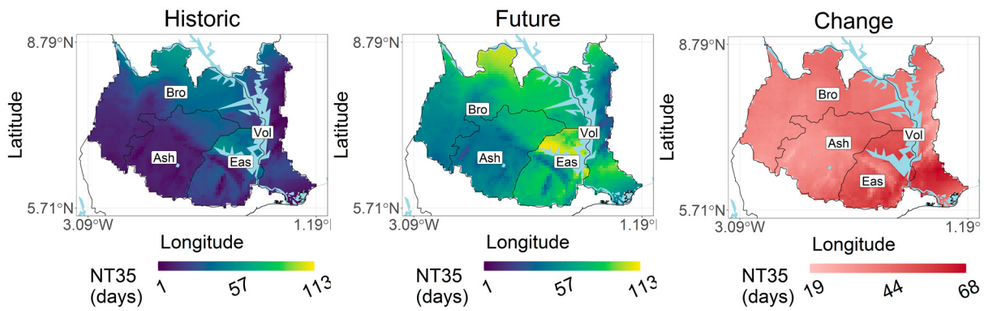
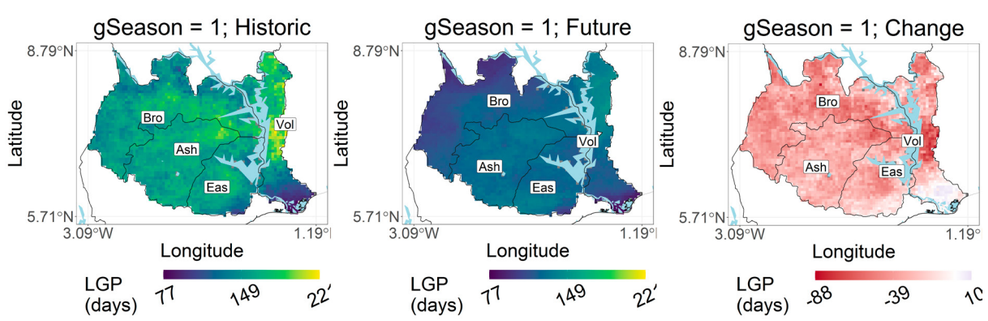


Figure 6. Historical (left), future projected (center) and projected change (right) for the total number of the days for the length of the first growing season (average of last 30 years) for the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.



5.3. Crop suitability analysis

The results of our crop suitability analysis, which accounts for precipitation and temperature, indicate that maize production is currently highly suitable (80-100%) to all four regions (Figure 7 and 8). In the future, less than 25% of the Volta Region will remain highly suitable, whereas most of the regions will become moderately suitable (40-80%). In the Eastern Region, the northern parts will it become moderately suitable (40-80%), while the south and central parts will remain highly suitable. However, in the future, nearly 60% of Ashanti and Brong-Ahafo and 75% of Eastern will become highly suitable, with the rest moderately suitable. In Volta, 50% of the land is highly suitable at present, and this suitability is expected to rise to nearly 60%; however, the south part of the region will become poorly suitable.

These results offer mixed opportunities, as suitability for rice production in Ghana increases, while suitability for maize production decreases. They suggest a need to enhance maize farmers' resilience to protect them from the effects of climate change effects and the expected reduction in crop suitability.

Figure 7. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of maize production in the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.

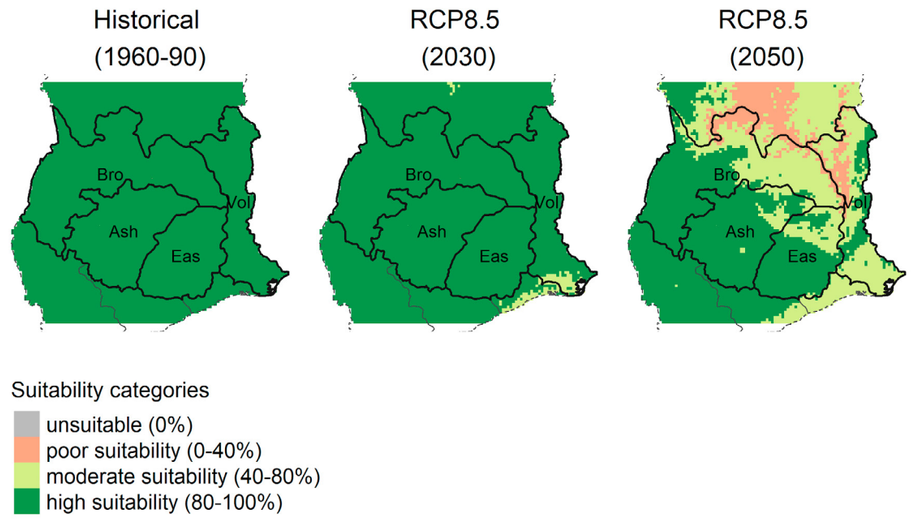


Figure 8. Suitability change of maize production in the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.

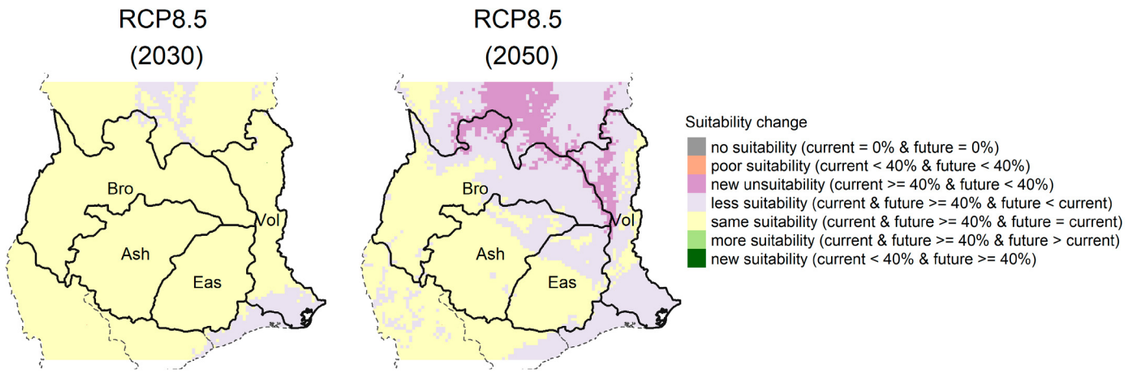


Figure 9. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of rice production in the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.

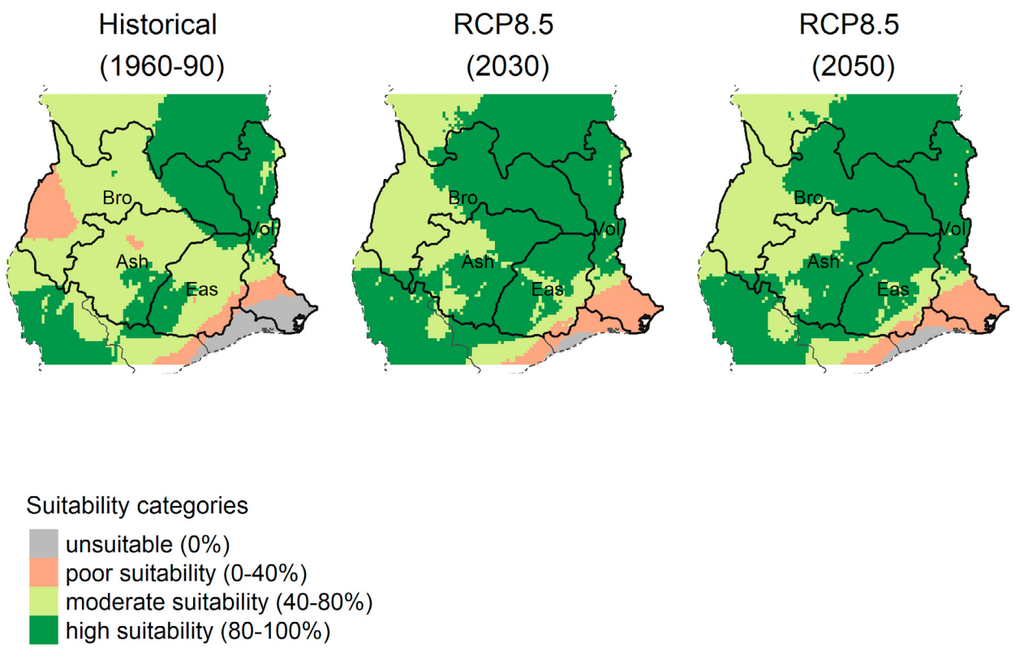
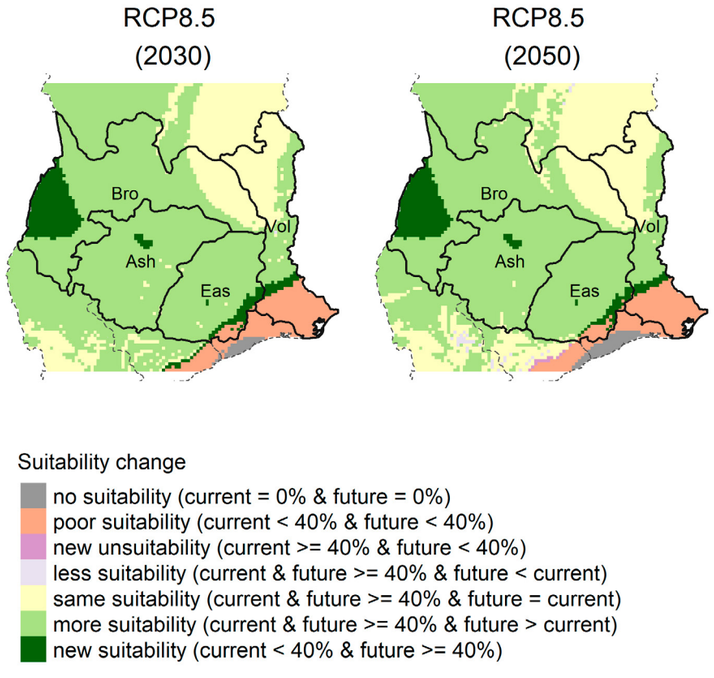


Figure 10. Suitability change of rice production in the Ashanti, Brong Ahafo, Eastern and Volta regions of Ghana.



5.4. Climate vulnerabilities across agriculture value chain commodities

Based on the results from our analysis, we conducted desk review of the most common hazards affecting the prioritized value chains.

5.4.1. Maize

The two main climatic hazards affecting the maize value chain are increased temperatures and reduced rainfall intensity, combined with a shortened growing season as predicted by the climate modelling results above. Higher temperatures result in an increased incidence of stem borers, herbicidal pests, and armyworms. Moreover, higher temperatures reduce germination rates and productivity. Maize production is severely impacted by seasons with high temperatures and reduced precipitation. In turn, reduced production decreases tradable volumes of maize, limiting the amount sold and thus negatively affecting both farmers and traders. A reduction in rainfall intensity coupled with a shorter growing season diminishes farmers' ability to produce quality maize. Shorter growing seasons are mainly the result of late onset and early cessation of rains. These two hazards (increased temperature and reduced rainfall) result in poor germination and crop failure, so that farmers have less income available to purchase inputs. However, shortened growing seasons mostly affect farmers who are unable to adjust their planting dates. Maize is vulnerable because it has many crop stages that are influenced by climatic conditions.

Increased temperatures and reduced rainfall intensity taken together result in reduced production and irregular income. This in turn lessens farmers' productivity in the next season, as well as their ability to market their produce and purchase necessary inputs like seeds and fertilizer. These consequences then affect other value chain actors. Retailers are forced to diversify their business and seek an alternative source of maize, for example. Eventually, these climatic hazards will increase Ghana's agricultural deficit.

5.4.2. Rice

The two main climatic hazards affecting the rice value chain are droughts and floods. The incidence of drought leads directly to increased water and heat stress. Water and heat stress in turn result in the formation of hardpans that constrain land preparation, and they also bring about increased cost of labour, plant withering, and reduced seed viability. Ghana has been experiencing increasingly frequent floods, with the most recent floods reported late last year (2019). Where flooding is severe enough to submerge rice plants, waterlogging, disease infestation, soil erosion, and nutrient leaching can lead to crop loss or failure. Severe flash flooding, creates gullies, erodes soil, destroys personal property and infrastructure, and results in land degradation. These impacts limit the movement of goods and inputs, affecting all actors along the value chain.

Droughts and floods lead to reduced rice production, affecting farmers' revenue and food sufficiency. In extreme cases of low output, brokers and processors must search for alternative sources of rice and diversify their businesses. Increased rice importation is the primary consequence when local rice production declines; this is an important consideration because Ghana is a net importer of rice.

6. ADAPTATION TO CLIMATE CHANGE AND VARIABILITY

KEY MESSAGES

- Most farmers in the maize and rice value chains have adopted coping strategies to climatic hazards.
- GIZ is training farmers in the system of rice intensification and value addition techniques for rice; in conservation agriculture and planting and irrigation techniques for maize; and in financial and entrepreneurial skills.
- Farmers' coping strategies include diversifying crops, applying fertilizer, planting early maturing seed varieties, changing crops species, shifting planting dates, and establishing crop-livestock systems.

6.1. On-farm adaptation strategies

GIZ, through Green Innovation Centers, has been implementing several practices to help enhance farmers' resilience and coping mechanisms. Along the maize and rice value chains, it has been training farmers in the use of improved seeds, good agricultural practices, improved water management, post-harvest management such as solar drying, basic soil management practices, and farm-level mechanization. Along the rice value chain, GIZ is training farmers in the system of rice intensification (SRI), in simple value addition techniques such as parboiling, and in marketing their end product.[4] Along the maize value chain, on the other hand, farmers are trained in conservation agriculture, e.g. minimum tillage; in irrigation for the production of green maize; and in planting techniques (Table 2). Some of the training is implemented through information and communication technology and by setting up demonstration areas. Additionally, GIZ is training farmers in the importance of community-based saving and in entrepreneurial and business skills through its farmers' business school.

Farmers have employed several coping strategies to maximize their production and limit the adverse effects of climate change risk. Their major adaptation strategies include crop diversification, crop rotation and mixed cropping, application of fertilizer, planting early maturing seed varieties, changing crops species, and shifting planting dates. Additionally, farmers are rearing livestock that they sell when the need to raise money arises, while other farmers borrow from friends and relatives; as indicated earlier, borrowing is among the main sources of credit in rural households. The government is also increasing irrigation facilities, thus enabling farmers' coping capability (Table 3).

4 Parboiling is a value-addition method that involves soaking, steaming, and drying rice. The final product is partially cooked rice that is packaged and sold. Consumers strongly prefer parboiled rice because it saves time during preparation.

Table 2. Specific practices within each practice group relevant to the focus value chains

PRACTICE GROUPS	MAIZE VALUE CHAIN	RICE VALUE CHAIN
Conservation agriculture	• Conservation agriculture, e.g. minimum tillage	
Crop rotation	• Crop rotation	
Integrated nutrient management	• Integrated nutrient management • Basic soil management practices	• Basic soil management practices
Production best practices	• Farm-level mechanization • Planting techniques	• Farm-level mechanization • Value addition techniques, e.g. parboiling
Improvement of rice management		• System of rice intensification (SRI)
Intercropping / diversification	• Mixed cropping • General good agricultural practices	• Good agricultural practices
Storage and post-harvest	• Post-harvest management, e.g. solar drying	• Post-harvest management, e.g. solar drying
Variety improvement	• Improved seeds	• Improved seeds
Water management	• Better water management • Irrigation for the production of green maize	• Better water management
Marketing	• Entrepreneurial and business skills	• Entrepreneurial and business skills ; Marketing end product
Finance	• Access to financial services • Community-based saving	• Access to financial services • Community-based saving

*Denotes that this is the highest-ranked adaptation strategy for its respective value chain.

Table 3. Adapting to climate change: strategies across major value chain commodities

MAIZE

	INPUT	ON-FARM	POST-HARVEST	MARKETING
Increased temperature	• Increased labour demand	• Inhibited germination • Development of hard soil pan	• Reduced maize yield • Poor quality of produce	• Reduced volume, which increases the market price for final consumers • Increased transaction costs for traders seeking new sources of maize • Underutilization of processors' plants and machinery
Reduction in rainfall intensity combined with a shortened growing season	• Increased labour demand	• Inhibited and poor germination • Crop failure • Development of hard soil pan	• Reduced maize yield • Poor quality of produce • Development of aflatoxins	• Reduced volume results in a high price for end consumers • Underutilization of processors' plants and machinery

Strategies to mitigate both hazards		
Farmers' coping strategies	• Diversifying crops • Rotating and mixing crops • Applying fertilizer • Planting early maturing seed varieties	• Changing crops species • Shifting planting dates • Rearing livestock • Irrigation
On-going adaptation strategies	• Use of improved seeds • Good agricultural practices • Improved water management • Post-harvest management • Basic soil management practices • Mechanization	• Conservation agriculture such as minimum tillage • Irrigation • Agribusiness • Value addition

RICE

	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• Increased labour demand • Increased demand for quality seed	• Inhibited germination due to reduced seed viability • Plant withering • Development of hard soil pans	• Reduced rice yield • Poor quality of produce	• Reduced volume, which increases the market price for final consumers
Floods	• Increased labour demand	• Water-logging • A buildup of weeds, pests, and diseases • A surge in human infectious diseases	• Reduced rice yield • Poor quality of produce	• Reduced volume, which results in a high price for end consumers

Strategies to mitigate both hazards		
Farmers' coping strategies	• Diversifying crops • Applying fertilizer • Planting early maturing and improved seed varieties	• Changing crops species • Shifting planting dates • Rearing livestock • Irrigation
On-going adaptation strategies	• Use of improved seeds • Good agricultural practices • Improved water management • Post-harvest management • Basic soil management practices	• Mechanization • SRI • Simple value addition techniques such as parboiling

6.2. Cost benefit analysis of the prioritized adaptation strategies

KEY MESSAGES

- Profitable coping strategies and GIZ-advocated practices for farmers include crop rotation, mixed cropping, the use of improved seed varieties, and integrated nutrient management.
- Benefits of these strategies include heightened productivity and cost reduction.

A CBA is critical to sound investment decisions, **including those associated with climate-smart agriculture (CSA) practices.** It allows for the comparison of costs and returns associated with a given CSA practice versus already existing practices (Ng'ang'a et. al., 2017). In a CBA, three indicators, the net present value (NPV), internal rate of return (IRR), and payback period are used to show the profitability associated with an improved practice.

In the case of Ghana, the NPV, IRR, and the payback period of some of the farmers' coping strategies and GIZ-advocated practices were obtained from the literature. The main innovations we identified in the literature include crop rotation, mixed cropping, the use of improved seed varieties, minimum tillage, and integrated nutrient management, as used by farmers of maize, cassava, okra, tomatoes, peppers, and watermelons (Ng'ang'a et. al., 2017). We considered all these practices to have a life span of 3 years. **All except for minimum tillage were profitable with a positive NPV and an IRR greater than the market discount rate (Table 4).** The main benefit associated with the innovations emanated from increased productivity and reduced costs of implementation and maintenance.

Table 4. Cost-Benefit Analysis results

VALUE CHAIN	INNOVATION	PROFITABILITY INDICATORS			
		NPV IN US$	IRR IN (%)	PAYBACK PERIOD (YEARS)	LIFE CYCLE
Maize, cassava, okra, tomatoes, peppers, beans, and watermelons	Crop rotation	2,614	69	1	3
Maize, cassava, okra, tomatoes, peppers, beans, and watermelons	Mixed cropping	359.6	62	1	3
Maize, cassava, okra, tomatoes, peppers, and watermelons	Improved seed varieties	1,348	107	2	3
Maize, cassava, okra, tomatoes, peppers, and watermelons	Minimum tillage	-2,945	(231)	N/A	3
Maize, cassava, okra, tomatoes, peppers, and watermelons	Integrated nutrient management	2,241	227	1	3

NB: (231) implies that the practice was not privately profitable, and as such, the payback could not be computed.

7. SYNTHESIS AND RECOMMENDATIONS

Historical data and future climate projections indicate that droughts, floods, high rainfall intensity, and high temperatures will affect crop and livestock production in Ghana. Climate change hazards coupled with low use of inputs and mechanization, a high poverty rate, land degradation, and poorly developed markets, together result in low agricultural production. **Farmers are acutely at risk because they are already vulnerable and highly dependent on rain-fed agriculture.**

Farmers' coping strategies include diversifying their crops, applying fertilizer, planting early maturing seed varieties, changing crops species, changing planting dates, and rearing livestock. For its part, the government has been implementing its fertilizer subsidy program, investing to upgrade irrigation facilities, and creating an environment conducive to collaborative work. GIZ, through Green Innovation Centers, is training farmers in the use and importance of improved seeds, good agricultural practices, better water management, post-harvest management, basic soil management practices, and farm-level mechanization, while also broadening access to financial services.

CBA is a very important tool for evaluating investments that require a decision to be made (i.e., whether to proceed with the investment or not). Despite the strength and limitation associated with the CBA methodology (i.e. potential inaccuracies during the identification and quantification of costs and benefits and hence NPV), CBA is critical for future planning of strategic investment. The results from the CBA indicate that some farmers' coping strategies and GIZ-advocated practices are profitable and should be encouraged for adoption among smallholder farmers.
Going forward, high potential activities for addressing climate risk in Ghana include practice groups spanning input optimization, good production practices, post harvest, marketing, and finance. A variety of opportunities for collaboration, funding, and synergies exist for these practices (Table 5). In general, the following partner organizations are well positioned to offer support across all potential interventions:

- Ghanaian government under the mandate of the National Climate-Smart Agricultural and Food Security Action Plan (2016-2020)
- A variety of Ghanaian government agencies work on agricultural policy, including the Ministry of Food and Agriculture.
- The Council of Scientific and Industrial Research works with universities and international research institutions like the International Food Policy Research Institute (IFPRI), CIAT, and the International Institute of Tropical Agriculture.
- Relevant NGOs and developmental partners, including the German Agency for International Cooperation, Africa Rising, the International Fund for Agricultural Development, the World Bank, the Food and Agriculture Organization, the United States Agency for International Development, the Alliance for a Green Revolution in Africa, and the Ghana Grains Council.

Further, common barriers that may challenge all climate-adaptive programming include high costs of inputs, high levels of poverty, low soil fertility, land degradation, low access to credit and other necessities, and poor infrastructure. For purposes of extension, Internet access is very limited, but a high proportion of Ghanaians own mobile phones.

However, to support the adoption of the practices mentioned in Table 5, as well as the achievement of a food-secure country and a reduction in the poverty level, the government must redouble its efforts to create a conducive environment to transform the agricultural sector. This can be done by enacting gender-inclusive policies and strategies, engaging in collaborative work with developmental partners, investing in improved infrastructure, and augmenting access to essential goods and services.

Table 5. Practice-group specific potential strategies and considerations for advancing CSA at scale

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Conservation agriculture	• Ghanaian government, Ministry of Food and Agriculture (Drought Management Plan) • Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy) • Council of Scientific and Industrial Research Soil Research Institute • Food and Agriculture Organization of the United Nations	**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:**** • Weak land tenure security • Inconsistent extension services • Poor financial service availability	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency
Crop rotation	• Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy)	**Farm level barriers:**** • Knowledge gaps • Financial constraints • Limited plot sizes **Institutional barriers:**** • Weak land tenure security • Inconsistent extension services • Poor financial service availability	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency
Integrated nutrient management	• Ghanaian government (Ghana National Fertilizer Subsidy Program) • World Bank: Sustainable Land and Water Management Project (2011-2020)	**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:** • High input costs • Low access to credit • Sale of adulterated agrochemicals, which reduces farmers' trust in input suppliers	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Production best practices	• Ghanaian government (Planting for Food and Jobs Flagship Project) • Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy) • Ghanaian government (Drought Management Plan) • Rising Africa and Feed the Future	**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:** • Limited access to credit • High interest rates • Demands for collateral	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability
Improvement of rice management	• Ghanaian government (National Rice Development Strategy) • Coalition for African Rice Development • Ghanaian government, Grain and Legumes Development Board	**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:**** • Weak land tenure security • Inconsistent extension services • Poor financial service availability	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability
Intercropping/ Diversification		**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:**** • Weak land tenure security • Inconsistent extension services • Poor financial service availability	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability
Storage and post-harvest	• Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy) • Rising Africa and Feed the Future	• Poor infrastructure, e.g. suboptimal roads • Underdeveloped markets, e.g. lacking coolers	• High potential for private sector investing	• Reduces losses, thus increasing profits and supporting markets stability, particularly inter-seasonally
Variety improvement	• Ghanaian government (Drought Management Plan) • Council of Scientific and Industrial Research Crops Research Institute • Council of Scientific and Industrial Research Plant Genetic Resources Research Institute	• Lack of funding for national research centers • Weak distribution networks	• International research funding offers robust support; diversification toward local and culturally important crops needed	• Supports climate-resiliency and yields, thus improving market stability
Water management	• Ghanaian government (Drought Management Plan) • Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy) • Ghanaian Irrigation Development Authority • Ghanaian Water Resource Commission • Council of Scientific and Industrial Research Water Research Institute • World Bank: Sustainable Land and Water Management Project (2011-2020)	• High levels of capital investment required. • Limited access to credit, high interest rates, demands for collateral • Insufficient infrastructure	• Public and private interests with good blended finance potential	• Supports climate-resiliency and yields, thus improving market stability
Marketing	• Ghanaian government, Ministry of Food and Agriculture (Food and Agriculture Sector Development Policy) • The International Fund for Agricultural Development: Ghana Agricultural Sector Investment Programme • German Agency for International Cooperation (farmers' business school)	• Insufficient farmer access to markets • Price differentials and fluctuations • Little control of pricing by farmers	• High potential for private sector investing	• Robust market access enables investment in improving farm resiliency and productivity
Finance	• Ghanaian government • German Agency for International Cooperation (farmers' business school)	**Farm level barriers:** • - **Institutional barriers:**** • Poor availability of farmer-targeted financial services, including loan, credit, savings, and warehouse receipts	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Enable on-farm investments in soil fertility, optimized management techniques, and climate resiliency

** based on literature

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9. ACKNOWLEDGMENTS

This study was conducted by the Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT), under the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), supported by the Green Innovation Centres for the Agriculture and Food Sector (GIC) implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) under the framework of the special initiative "ONE WORLD – No Hunger" on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The document has been developed by George Kanyenji under the technical leadership of Stephanie Jaquet, Caroline Mwongera, Stanley Karanja and Evan Girvetz and with contributions from the climate modelling team: Harold A.E. Achicanoy, Alejandra Esquivel, Aniruddha Ghosh, Julian Ramirez-Villegas and the agricultural economics team: Devinia Akinyi, Dorcas Jalango, Bwema Ombati.

We acknowledge the contribution of the project manager for GIZ: Bjoern Hecht, Heike Herden.

Technical review and editing: Annalese Duprey, Stephanie Pentz, Mehrey Vaghti, and Megan Mayzelle

Infographics and layout: Katya Kuzi

This document should be cited as:

Bioversity International & CIAT, CGIAR CCAFS, and GIZ. 2020. Adapting Green Innovation Centres to Climate Change: Analysis of value chain adaptation potential. Maize and Rice Value Chains in the Ashanti, Brong Ahafo, Eastern and Volta regions, Ghana

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